NASA TECHNICAL TRANSLATION NASA TT F-16224

RELATION BETWEEN THE WIND AND PRESSURE FIELDS IN THE STRATOSPHERE AND LOWER MESOSPHERE OF THE TROPICAL REGION OF THE NORTHERN HEMISPHERE

L. S. Minyushina

Tsentral'naya Aerologicheskaya Observatoriya
Leningrad, USSR

Translation of "O svyazi vetrovogo i baricheskogo poley v stratosfere i nizhney mezosfere tropicheskoy zony Severnogo polushariya," Meteorologiya i Gidrologiya, No. 8, August 1974, pp. 37-45.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 MARCH 1975

STANDARD TITLE PAGE

1. Report No. NASA TT F-16224	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle RELATION BETWEEN THE WIND & PRESSURE FIELDS IN THE STRATOSPHERE & LOWER MESOSPHERE OF THE TROPICAL REGION OF THE NORTHERN HEMISPHERE		5. Report Date March 1975
		6. Performing Organization Code
7. Author(s) L. S. Minyushina Tsentral'naya Aerologicheskiya Observatoriya		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, California 94063		11. Contract or Grant No. NASw-2481
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes
Translation of "O sv'azi vetrovogo i baricheskogo poley v stratosfere i nizhney mezosfere tropicheskoy zony Severnogo polushariya," Meteorologiya i Gidrologiya, No. 8, Aug. 1974, pp. 37-45.

16. Abstract The relation between the wind and pressure fields in the stratosphere of the tropical zone in the northern hemisphere is examined, on the basis of analysis of spatial and time profiles of the zonal wind field and contour charts of the 10 mb and 2 mb surfaces. Variability of the pressure field in the quasi-biennial circulation cycle is compared with that in the semiannual cycle.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified-Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	14	

RELATION BETWEEN THE WIND AND PRESSURE FIELDS IN THE STRATOSPHERE AND LOWER MESOSPHERE OF THE TROPICAL REGION OF THE NORTHERN HEMISPHERE

L. S. Minyushina

Tsentral'naya Aerologicheskaya Observatoriya
Leningrad, USSR

Great importance has been given in recent years to studies of the synoptic, large-scale processes in the stratosphere and lower mesosphere. This is due primarily to the requirements for improvement of weather forecasts [1, 5]. /37*

At the present time, absolute contour charts are regularly constructed and published for the middle stratosphere of the northern hemisphere, up to the 10 mb surface (30-32 km), inclusive. 2, 0.4 and 0.1 mb isobar charts for the northern hemisphere also are constructed and analyzed in the Central Aerological Observatory [3, 4], from Soviet and foreign rocket measurement data of the temperature, pressure and wind in the upper stratosphere and lower mesosphere. These charts basically show good agreement with the synoptic processes in the middle and upper stratosphere, as well as specific differences in them.

However, the upper stratosphere charts are constructed, either from averaged data or for individual synoptic situations, and they are primarily related to the high and middle latitudes. Their use for analysis of the tropical zone is difficult at present. Concerning the equatorial region, the earlier conclusion from everyday experience of weather forecasters [12], that wind data there are more representative of description of atmospheric processes than the pressure field, obviously should be kept in mind. Since the

* Numbers in the margin indicate pagination in the foreign text.

expression for the geostrophic wind loses meaning in the equatorial zone, the air flow field in the free atmosphere should also provide more detailed and interesting information on large-scale processes there than the contour charts.

To examine the problem of the connection of the wind and pressure fields in the tropical zone of the northern hemisphere, we analyzed the 30 and 10 mb isobar charts (daily and average monthly) for 1965-1969 [10]. Comparison of the average monthly values of the zonal wind speeds and directions in the 24-32 km altitude region in spatial profiles of the wind field (Fig. 1), constructed from the data of 5 atmospheric rocket sounding stations [8] in the tropical zone of the Atlantic Ocean (Wallops, 37.8°N latitude, /38
75.5°W longitude; Cape Kennedy, 28.5°N latitude, 80.5°W longitude; Grand Turk Island, 21.5°N latitude, 71.2°W longitude; Antigua Island, 17.1°N latitude, 61.8°W longitude; Fort Sherman, 09.3°N latitude, 80.0°W longitude; Ascension Island, 08.0°S latitude, 14.5°W longitude), with the contour charts disclosed a close connection of the wind field structure in the tropical zone with the position of the subtropical high pressure regions.

The charts show that the subtropical high pressure regions are observed as independent pressure formations in the upper-air 10 and 30 mb isobar surfaces from September to April.

Since the spatial profiles of the wind field in the northern hemisphere, which we constructed refer to the Caribbean Sea area, the boundary between the westerly and easterly winds (0 isotach) at altitudes of 24-32 km (Fig. 1) apparently coincides with the po- /39
sition of the axis of the subtropical high pressure zone on the 10 and 30 mb charts, above the area of the Atlantic being studied. West winds are observed in that part of the subtropical high pressure zone, which is located to the north of this axis. East winds predominate in the southern part of the subtropical high pressure

zone. Here, the pressure decreases somewhat towards the equator, which determines easterly transport of the air in the equatorial stratosphere.

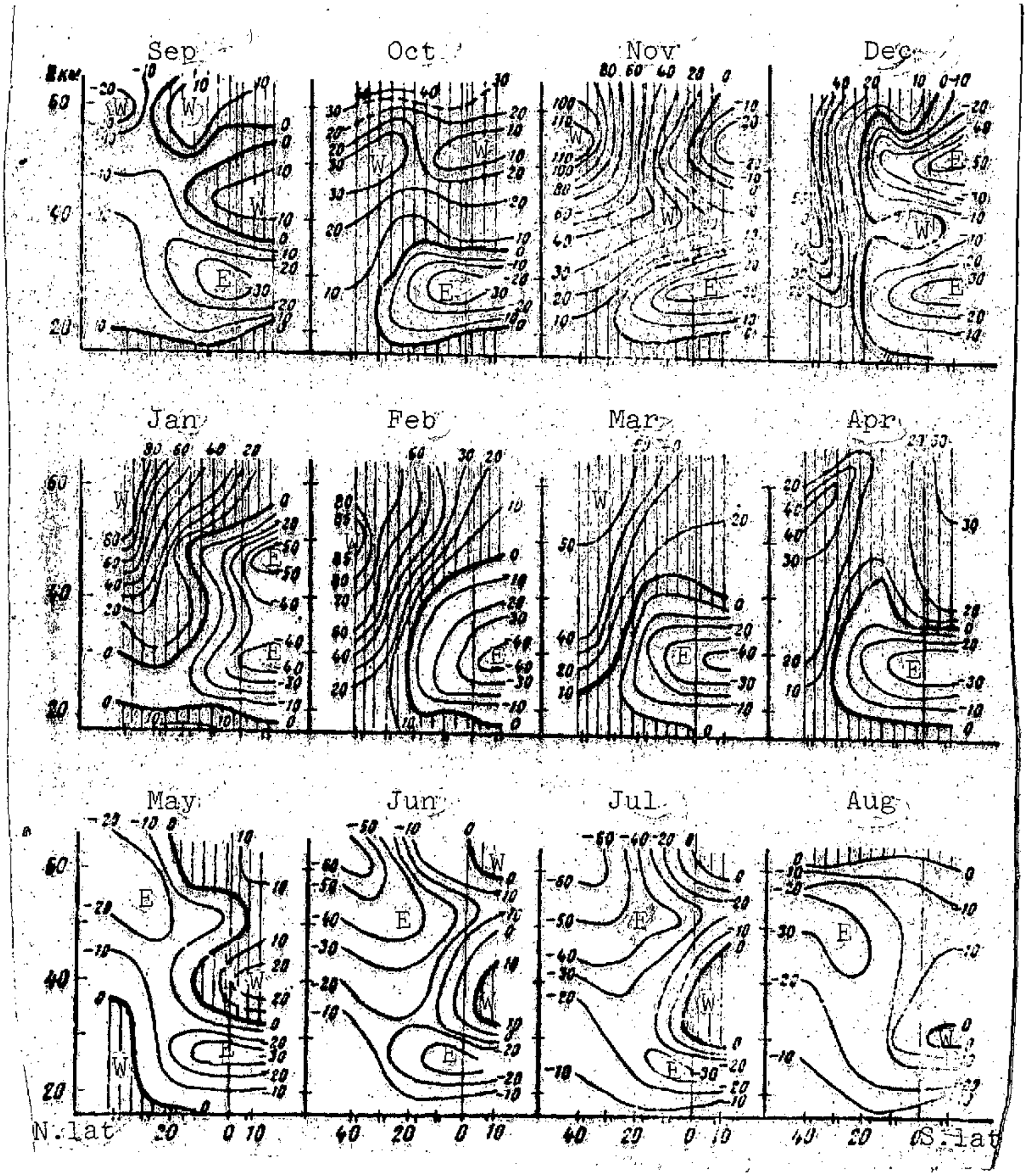

Fig. 1. Spatial profiles of zonal components of wind from 38°N latitude to 8°S latitude, between 75.5° and 14.5°W longitude; Septemper 1967-August 1968.

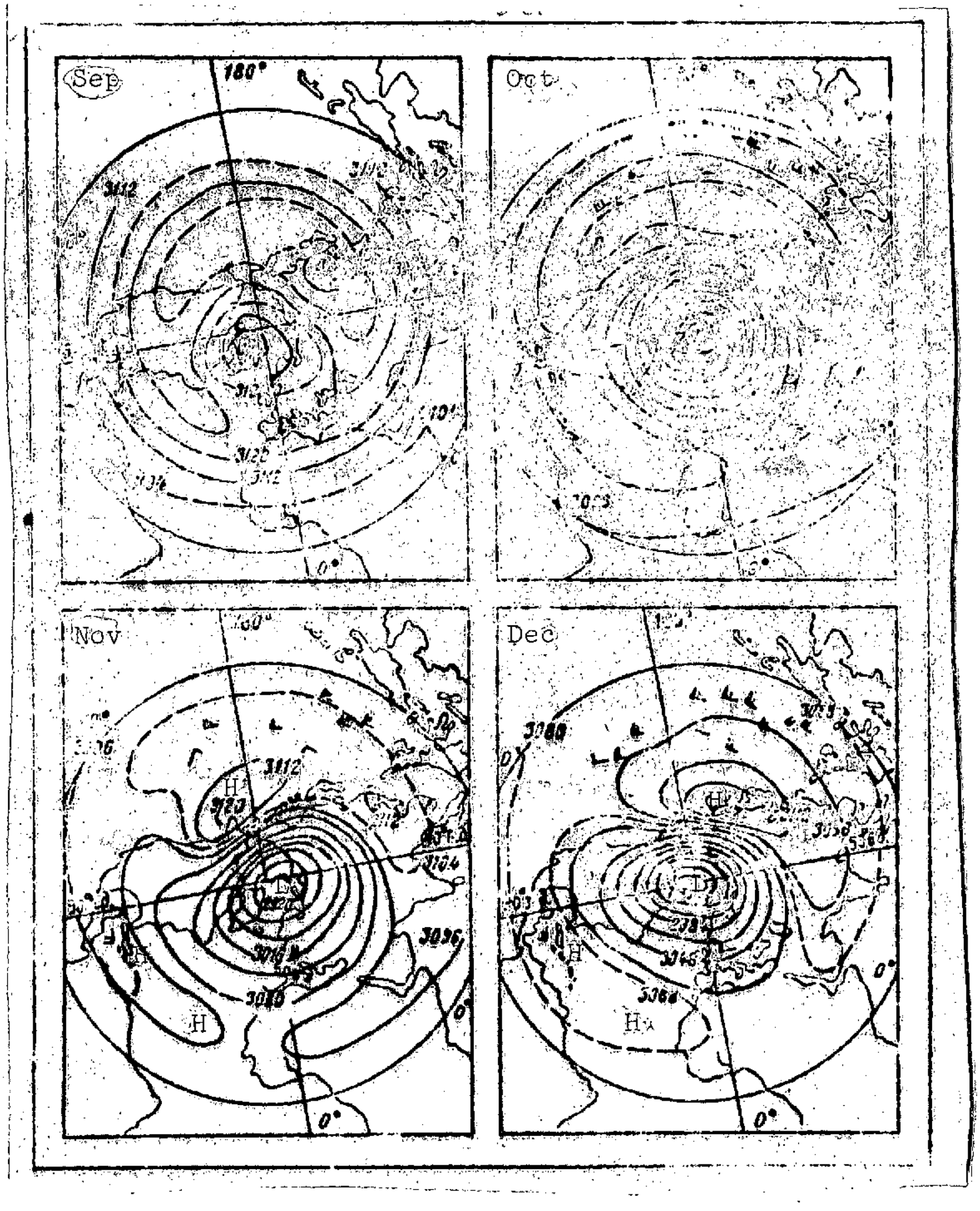

Fig. 2. Absolute contour charts of 10 mb isobar surface for September-December 1967.

Let us examine the location of the subtropical high pressure areas on the average monthly charts of the 10 mb surface above the northern hemisphere, in the period from September 1967 to April 1968 (Figs. 2, 3). In September 1967 (Fig. 2), in a period when formation of a polar low pressure area took place, the axis of the subtropical high pressure zone in the Pacific Ocean area passed /40 along 40-45 N latitude. It was somewhat to the south above the Atlantic Ocean (at approximately 40°N latitude). In September 1967, the east winds at this level enveloped an extensive region between 8°S latitude and 38°N latitude, in the spatial profile (Fig. 1).

In the succeeding months, as the polar low pressure area deepened and extended over a large area of the high latitudes of the northern hemisphere, the subtropical high pressure zone was displaced to lower latitudes. Thus, in November 1967 (Fig. 2), when it still encompassed the subtropical latitudes over almost the entire northern hemisphere, being broken only above the west coast of Africa, the axis of this zone above the Pacific Ocean was at approximately 25-27°N latitude, and, in the Atlantic Ocean area, it passed still further south, approximately along 20-22°N latitude. This location of it is confirmed by the location of the boundaries of /41 the equatorial east winds in Fig. 1, which we found and analyzed in detail in work [6].

The southernmost location of the axis of the subtropical high pressure belt should have been occupied in December-February, in the period of greatest development of the polar stratospheric low pressure area. However, the high pressure belt is not uniform in the wintertime. Maximum pressure foci are distinguished in it, from which stable pressure formations, the Aleutian and Atlantic high pressure areas, then develop. During the winter months, these high pressure areas are activated, and they cause disturbances in the polar low pressure area conditions. Their development is easily followed on the 10 mb surface charts for December 1967 (Fig. 2) and January 1968 (Fig. 3). In this case, the following circumstances attract attention: the strengthening of the Aleutian and Atlantic high pressure areas noted on these charts takes place in a period of maximum development of the summer stratospheric circulation in the southern hemisphere, i.e., when spreading of the east winds of the semiannual cycle in the stratosphere of the northern hemisphere takes place. Thus, for example, it follows from an analysis of Fig. 1 that, in December 1967 and January 1968, the speeds of the east winds of the semiannual cycle in the upper stratosphere and of the equatorial east winds in the middle stratosphere were on the order of 30-50 m/sec.

In February 1968 (Fig. 1), replacement of the easterly component of the semiannual cycle by the westerly took place in the equatorial atmosphere, above 46-48 km. At this time, the east winds of the semiannual cycle turned out to be forced downward, into the middle layer of the stratosphere, where they combined with the eastern equatorial winds, into a single circulation system. On the 10 mb surface chart (Fig. 3), the polar low pressure area recovered its normal shape in February. The pressure in the center of it decreased from that in January, and the Aleutian and Atlantic highs were displaced to subtropical latitudes.

In March-April 1968, a gradual reduction in size and destruction of the polar low took place and, correspondingly, expansion of the subtropical high pressure belt at the altitude of the 10 mb surface (Fig. 3). This process was manifested by a change in location of the 0 isotach, separating the west winds from the equatorial east winds in Fig. 1. In May 1968, the low pressure vortex above the polar region was replaced by high pressure and the subtropical high pressure region went into the stratospheric high pressure system. From May to August, the latter was a very stable pressure formation, in which eastward transport of the air over the entire northern hemisphere prevailed.

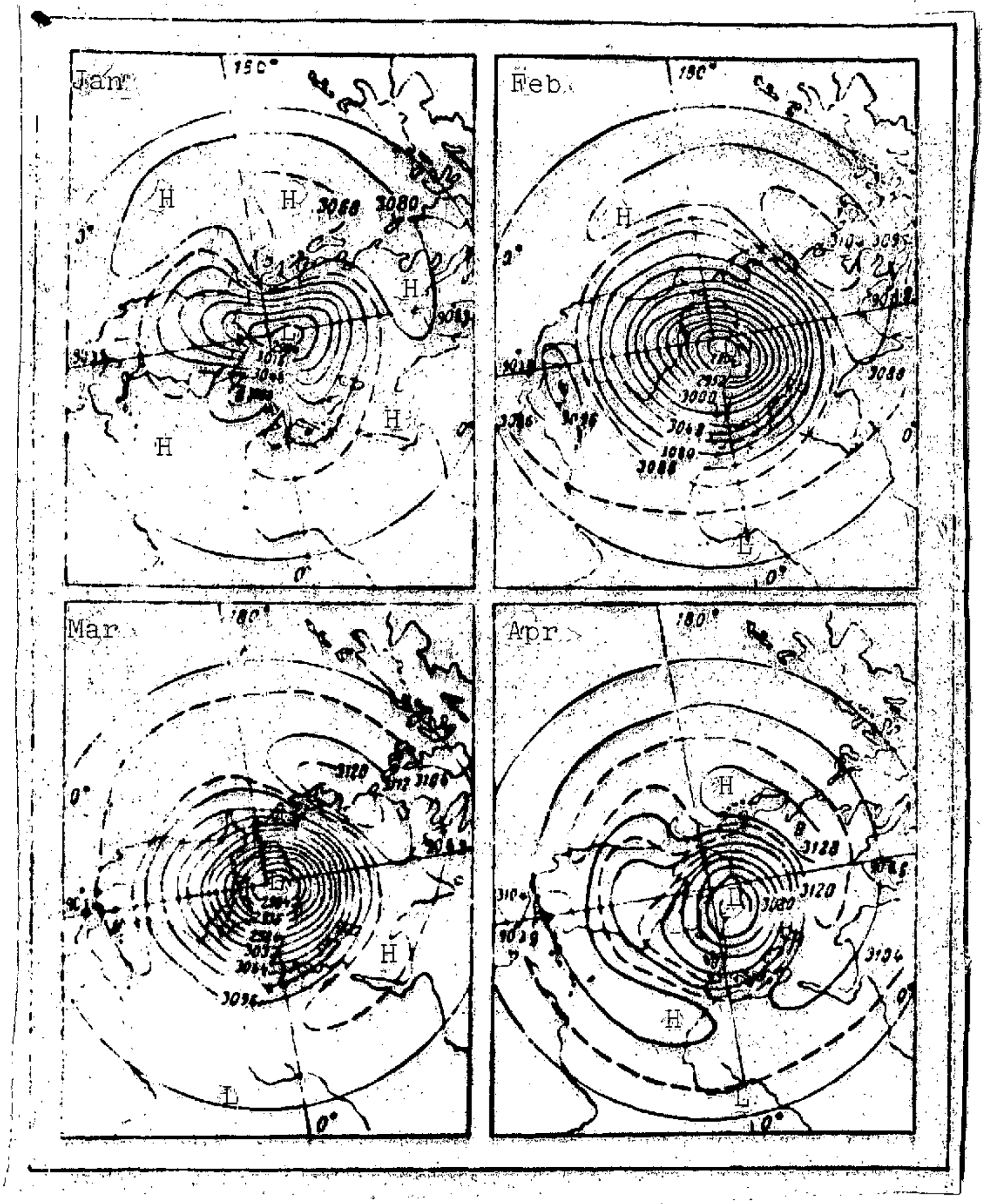

Fig. 3. Absolute contour charts of 10 mb isobar surface for January-April 1968.

An analysis of the wind field in the equatorial stratosphere, carried out on the basis of spatial profiles of the wind field, showed that the equatorial east wind system, initially forming from the east winds of the semiannual cycle, gradually spread to the lower layers of the stratosphere. This phenomenon apparently was caused by a similar shift of the subtropical high pressure zone. The presence of this phenomenon is generally confirmed by analysis of the 50, 30 and 10 mb surface contour charts. Like the equatorial east wind system, defining the easterly phase (component) of the quasi-biennial circulation cycle, the subtropical high pressure belt apparently exists in the middle stratosphere for quite long periods of time (on the order of a year) and is a global pressure formation.

The question arises: Are the subtropical low pressure regions on the 10 mb surface charts and those of still higher altitudes, /42 for example, on the 2 and 0.1 mb surface charts, single pressure formations over the entire stratosphere and lower mesosphere?

By analogy with the 10 mb surface charts, it can be considered that the location of the 0 isotach in the upper stratosphere and lower mesosphere coincides on the spatial profiles (Fig. 1) with the position of the maximum surface pressure in the subtropical high pressure belt of the northern hemisphere. Then, for example, during the period of greatest development of the easterly transport in the stratosphere of the southern hemisphere, the presence of two east wind maxima in the tropical latitudes of the northern hemisphere in the spatial profiles mentioned above leads to the thought that there are two independent high pressure regions, one of which defines the easterly phase of the quasi-biennial circulation cycle and the other, the easterly phase of the semiannual circulation cycle.

In periods of equivalent force, the high pressure regions apparently are forced from the upper stratosphere to the middle layers of the stratosphere. There, they combine into one high pressure system. Therefore, it might be said that the nature of the change in the pressure field in the upper stratosphere is different than that in the middle stratosphere. Thus, for example, the period of existence of the subtropical high pressure belt and of the high pressure areas above the oceans included in it in the winter months in the upper stratosphere must be shorter than in the middle stratosphere. This is in accordance with the development of the easterly phase of the semiannual circulation cycle. In periods of close to equal force, the development of the west winds of the semiannual circulation cycle, the polar low pressure area probably spreads over the entire hemisphere.

Consequently, the pressure field in the upper stratosphere and lower mesosphere of the tropical zone must be more changeable than that in the middle stratosphere over a period of a year, and the latitude shifts of the high pressure centers in the winter months, especially in the stratopause region, must be more rapid than in the middle stratosphere.

The hypothesis expressed above, as to the nature of the change in the pressure field in the stratosphere and lower mesosphere of the tropical zone is confirmed by the results of rocket and radiosonde measurements, obtained, not only over the Atlantic ocean, but in other low latitude areas of the earth. In the work of S. S. Gaygerov [4], by means of analysis of the 2 mb surface contour chart, it was demonstrated that independent higher pressure centers are distinguished in the tropical latitudes of the Pacific, Atlantic and Indian Oceans, in the high pressure region framing the winter polar low in the upper stratosphere and lower mesosphere. We note that a high pressure area above the Indian Ocean is not found, as a rule, on the 10 mb surface charts, but that it is seen distinctly in the upper stratosphere.

It should be noted that, until recently, atmospheric processes above this region have been studied little. In the Soviet Union, much attention has been given in recent years, to study of the circulation processes in the stratosphere and lower mesosphere in the Indian Ocean area. Specialists of the Central Aerological Observatory organized regular sounding of the atmosphere with meteorological rockets, at the Tumba firing range (8.5°N latitude, 76.9°E longitude), beginning in December 1970.

Time profiles of the zonal wind field for December 1970 are represented in Fig. 4. They were constructed from the data of four equatorial stations, two of which are in the Atlantic Ocean area (Ascension Island and Fort Sherman), one in the Pacific Ocean (Kwajalein Island, 8.7°N latitude, 167.7°E longitude) and one in the /43
Indian Ocean region, Tumba.

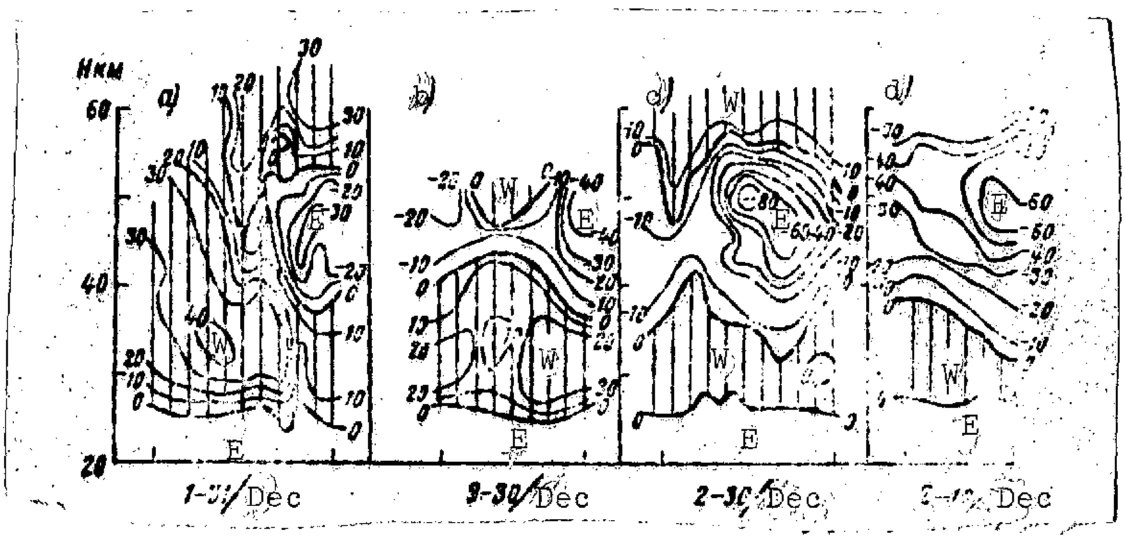

Fig. 4. Time profiles of zonal wind components for December 1970, above stations: a) Kwajalein Island; b) Tumba; c) Fort Sherman; d) Ascension Island.

It follows from Fig. 4 that, in December 1970, the easterly phase of the quasi-biennial cycle was replaced by the westerly, above the stations mentioned. The equatorial east winds of the quasi-biennial cycle were observed in the stratosphere below 25 km. The approximately identical altitude of their upper boundaries above all the stations discussed attracts attention. Replacement of the easterly phase by the westerly also was noted, from the data of the scientific research ships, Akademik Korolev, Akademik Shirshov and A. I. Voyeykov, which crossed the equator in the Pacific Ocean in December 1970 and January 1971 [2].

Above Ascension Island (Fig. 4), an eastern circulation characteristic of the summer (southern) hemisphere, was observed in the upper stratosphere and lower mesosphere, in December 1970. According to the data of the remaining three stations, located in the winter (northern) hemisphere, the east winds were found only in the upper stratosphere, but west winds were predominant in the lower mesosphere. The east winds in the upper stratosphere above Fort Sherman appeared at the end of November. The primary maximum of their speeds, as above Ascension Island, occurred in the middle of December.

Above Kwajalein Island, the east winds of the semiannual cycle appeared in the last 10 days of December, i.e., the eastern phase of the cycle in the Pacific Ocean area began somewhat later than in the Atlantic area. Above the Indian Ocean, the replacement of the westerly phase of the semiannual cycle by the easterly probably took place at the same time as above Fort Sherman, but east winds were observed in a thinner layer of the atmosphere, than above the Atlantic Ocean (Fig. 4).

Thus, the atmospheric rocket sounding data in the equatorial latitudes of the Atlantic, Indian and Pacific Oceans show that no longitudinal differences in appearance of the quasi-biennial circulation cycle in December 1970 were found. At the same time, analysis of the semiannual circulation cycle in the upper stratosphere and lower mesosphere of the northern hemisphere indicates an irregular onset of the easterly phase of this circulation cycle.

A similar phenomenon apparently occurred in 1966, in the equatorial stratosphere of the southern hemisphere. In the work of Quaroz and Miller [11], wind measurements in 1966, above rocket /44
sounding points (Ascension Island and the station in Natal, Brazil, 6°S latitude), are presented. It follows from them that the easterly phase of the semiannual circulation cycle above Ascension Island began in June, and that the east winds above the Natal station appeared a month later, in July. Consequently, appearance of the semiannual cycle may be somewhat different in different longitude zones.

Analysis of the 10 mb surface charts and the vertical zonal wind component profiles above the Atlantic area showed that the subtropical high pressure belt in the middle and lower stratosphere was very stable. This apparently determines the great uniformity of the quasi-biennial cycle above various low latitude areas of the earth. Nevertheless, small longitude differences should be observed in the quasi-biennial circulation cycle region. We have noted, in the 10 mb surface isobar charts (Figs. 2, 3), that the latitude of the subtropical high pressure regions above the Atlantic and Pacific Oceans are not the same. The axis of the subtropical high pressure belt in the Atlantic Ocean is located at lower latitudes than in the Pacific Ocean, as a rule. This means that the equatorial east winds above the Pacific Ocean extend to higher latitudes generally than in the Atlantic Ocean.

The latitude region, in which the quasi-biennial circulation cycle is observed, probably is somewhat wider above the Pacific Ocean than above the Atlantic. It possibly is somewhat narrower above the continents than above the oceans. This hypothesis is confirmed by the work of Ebdon [9] and Belmont and Dartt [7], in which global charts of the zonal wind field are presented.

We showed in [6] that the intensity of the eastern circulation in the stratopause region (close to 50 km) turned out to be less above Fort Sherman than above Ascension Island. This difference probably is connected with the fact that Fort Sherman is a coastal station, and the western periphery of the Atlantic high is located above it more often. This should be expressed in the wind field, by an increase in the meridional and a weakening of the zonal components of the wind.

If we had data from systematic measurements of the wind above the central areas of northern Africa or America, we would probably see that the speed of the east winds of the semiannual cycle there are still less, than above the coastal stations mentioned.

All this probably has to be taken into account in analysis of such problems of modern meteorology as comparison of intensity of the stratospheric circulation of the northern and southern hemispheres, as well as in using atmospheric rocket sounding data for weather forecasting.

In closing, the following can be concluded:

1. The equatorial east wind circulation system is determined by the existence of subtropical high pressure zones (in the northern and southern hemispheres), which are very stable global pressure formations in the middle and lower stratosphere. The changes in positions of these zones over time and their vertical distribution determines the quasi-biennial variations in circulation.

2. Changes in structure of the pressure field in the upper stratosphere and lower mesosphere should be greater than in the middle stratosphere, over a period of a year. This can be expressed by a more significant shift of the high pressure centers, both in the latitudinal and in the meridional directions, as well as by /45
changes in dimensions of the high pressure areas, which should lead to appearance of phase differences in appearance of the semiannual circulation cycle in different longitude zones.

REFERENCES

1. Bugayev, B. A., A. L. Kats and A. I. Ugryumov, "Biennial cycle in atmospheric circulation," in the collection Problemy obshchey tsirkulyatsii atmsofery [Problems of General Circulation of the Atmsophere], Leningrad, "Gidrometeoizdat" Press, 1972, pp.68-78.

2. Bugayeva, I. V., A. I. Ivanovskiy, G. A. Kokin, Yu. P. Koshel'kov, S. P. Perov, L. A. Ryazanova and D. A. Tarasenko, "Preliminary results of strato-mesospheric rocket experiment," Meteorologiya i gidrologiya 10, 3-11 (1971).

3. Gaygerov, S. S. and E. D. Zhorova, "Data on circulation and synoptic processes in the upper stratosphere of the northern hemisphere," Trudy TsAO, issue 85, 37-54 (1968).

4. Gaygerov, S. S. and M. Ya Kalikhman, "Synoptic maps of the upper stratosphere and lower mesosphere of the northern hemishpere," Ibid., issue 93, 50-81 (1970).

5. Kats, A. L., Tsirkulyatsiya v stratosfere i mezosfere [Circulation in the Stratosphere and Mesosphere], Leningrad, "Gidrometeoizdat" Press, 1968, p. 204.

6. Minyushina, L. S., "Structure of the zonal wind field in the stratosphere and lower mesosphere of tropical regions in periods of equal force," Meteorologiya i gidrologiya 5, 40-49 (1973).

7. Belmont, A. D. and D. G. Dartt, "The variability of tropical stratoshperic winds," J. Geophys. Res. 75/15, 3133-3145 (1970).

8. Data Report of the Meteorological Network Firngs, 1967-1968.

9. Ebdon, R. A., "A note on equatorial atmospheric winds," Meteorol. Mag. 101/1197, 110-117 (1972).

10. Kirch, R., B. Kriester, K. Labitzke, R. Scherhag and R. Stuhrmann, "Daily and Monthly Northern Hemisphere 10-Millibar Synoptic Weather Maps," Meteorol. Abh., Inst. Meteorol. u. Geophys., Berlin, 1965-1969.

11. Quaroz, R. S. and A. J. Miller, "Note on the semiannual wind variation in the equatorial stratosphere," Mon. Weather Rev. 95/9, 635-641 (1967).

12. Watts, J. E. M., Equatorial Weather with Particular Reference to Southeast Asia, London, 1955.